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Luo et al.

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(54) **WAFER-LEVEL PACKAGE STRUCTURE**

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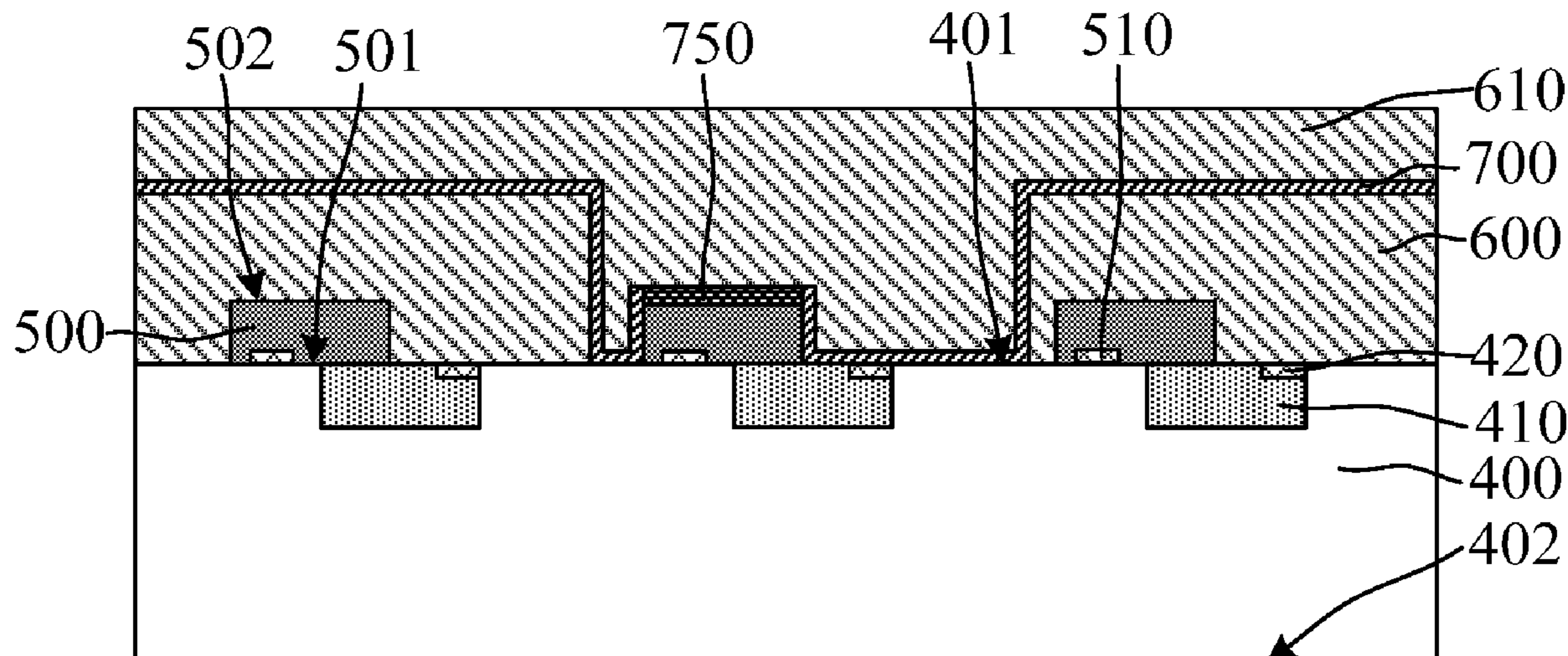
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(57) **ABSTRACT**

Wafer-level packaging structure is provided. First chips are bonded to the device wafer. A first encapsulation layer is formed on the device wafer, covering the first chips. The first chip includes: a chip front surface with a formed first pad, facing the device wafer; and a chip back surface opposite to the chip front surface. A first opening is formed in the first encapsulation layer to expose at least one first chip having an exposed chip back surface for receiving a loading signal. A metal layer structure is formed covering the at least one first chip, a bottom and sidewalls of the first opening, and the first encapsulation layer, followed by an alloying treatment on the chip back surface and the metal layer structure to form a back metal layer on the chip back surface.

7 Claims, 5 Drawing Sheets



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continuation of application No. PCT/CN2018/113107, filed on Oct. 31, 2018.

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H01L 23/31 (2006.01)
H01L 25/065 (2006.01)
H01L 25/00 (2006.01)
H01L 23/552 (2006.01)

- (52) **U.S. Cl.**
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 See application file for complete search history.

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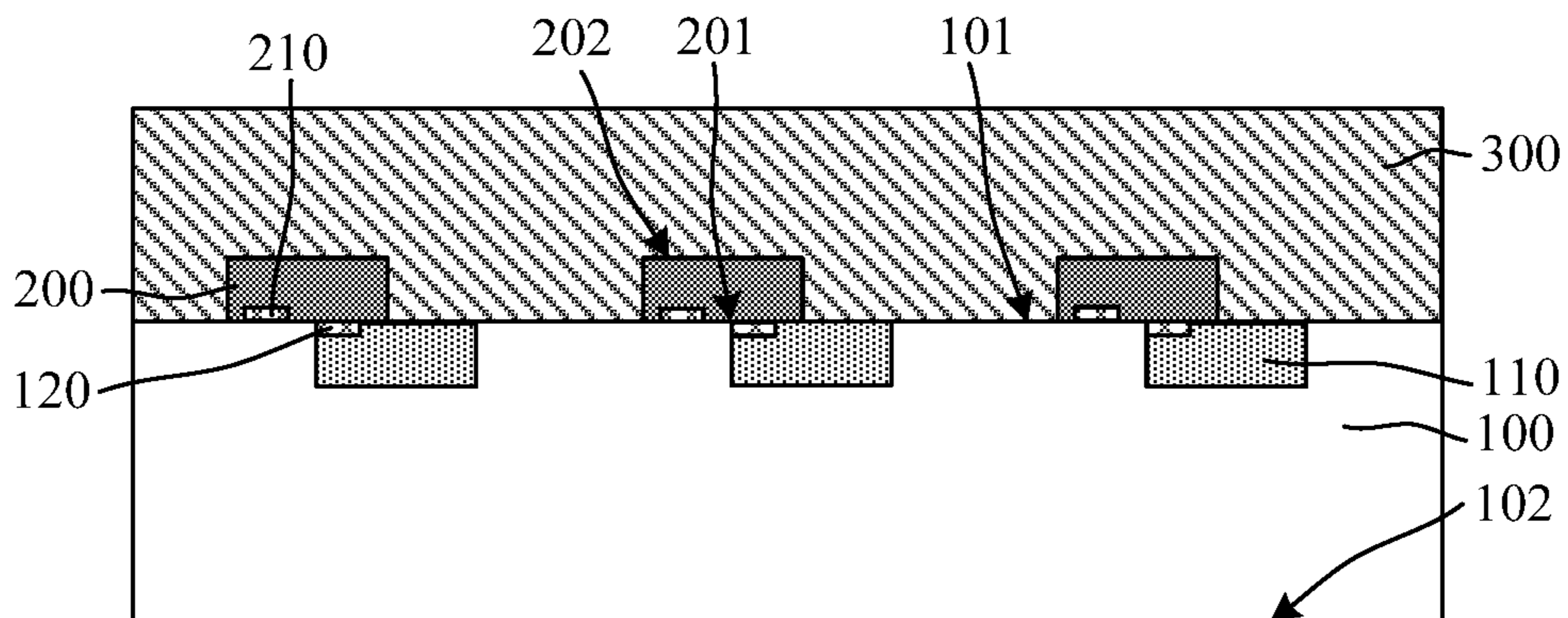


FIG. 1

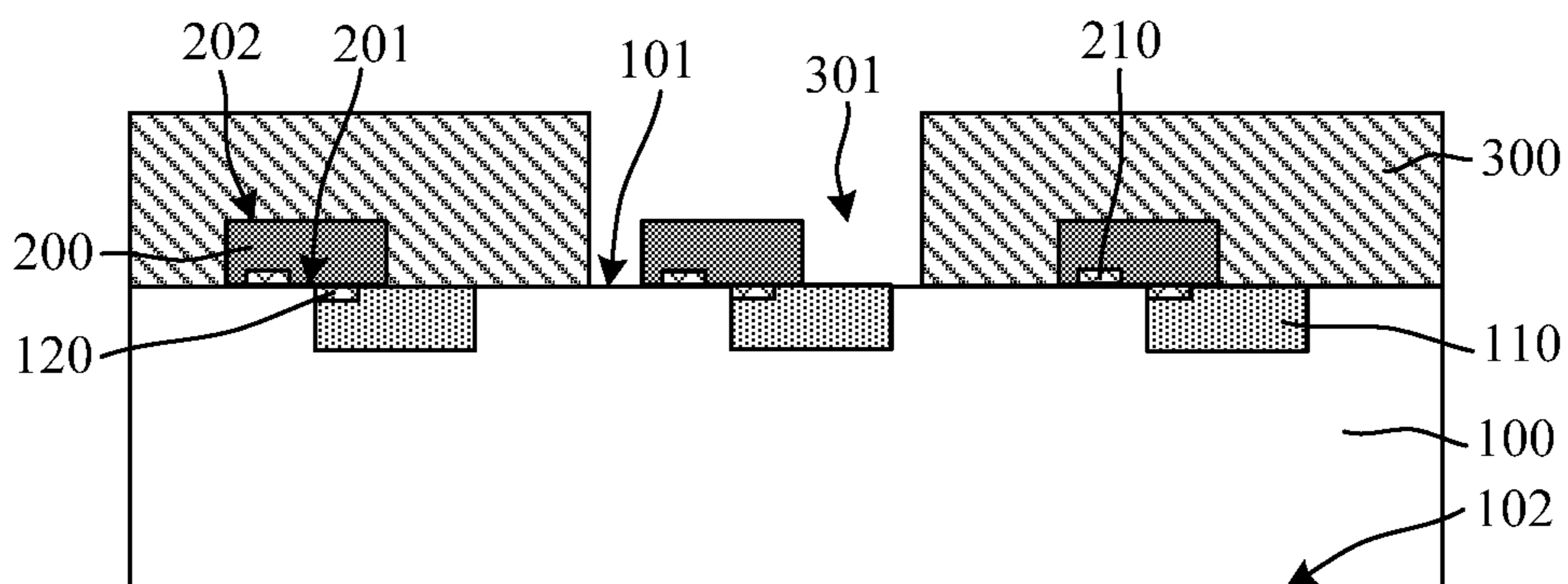


FIG. 2

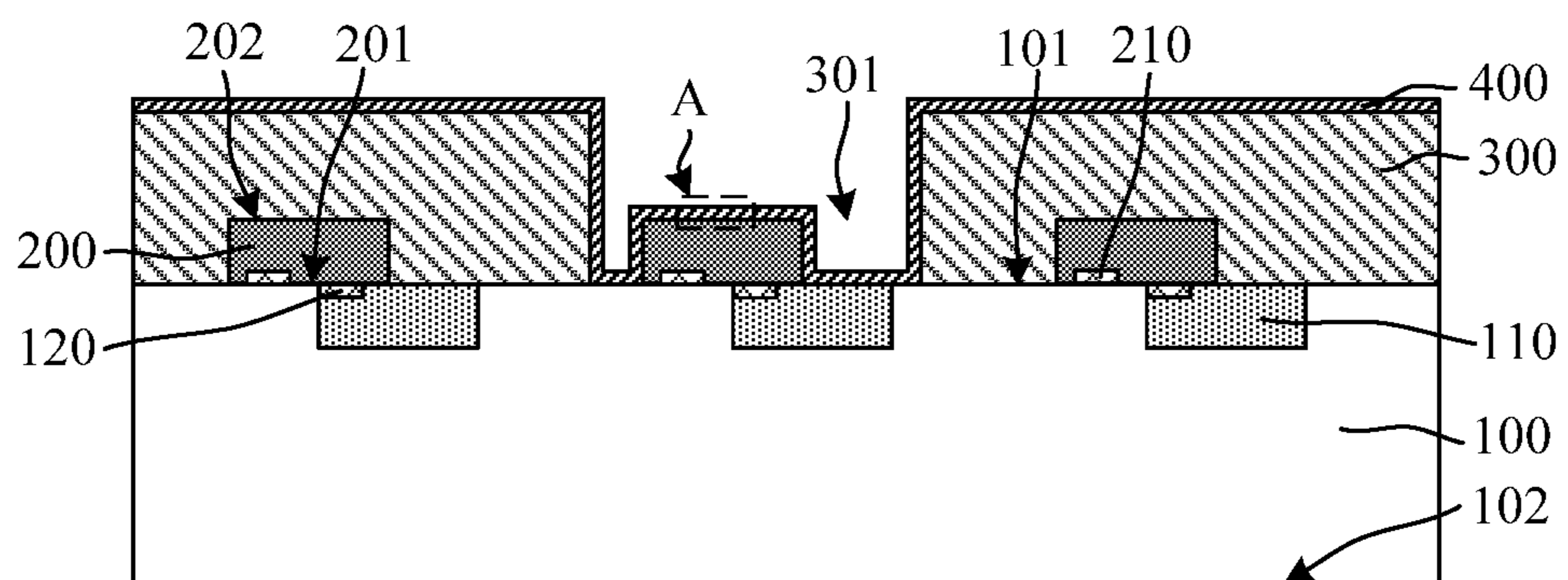


FIG. 3

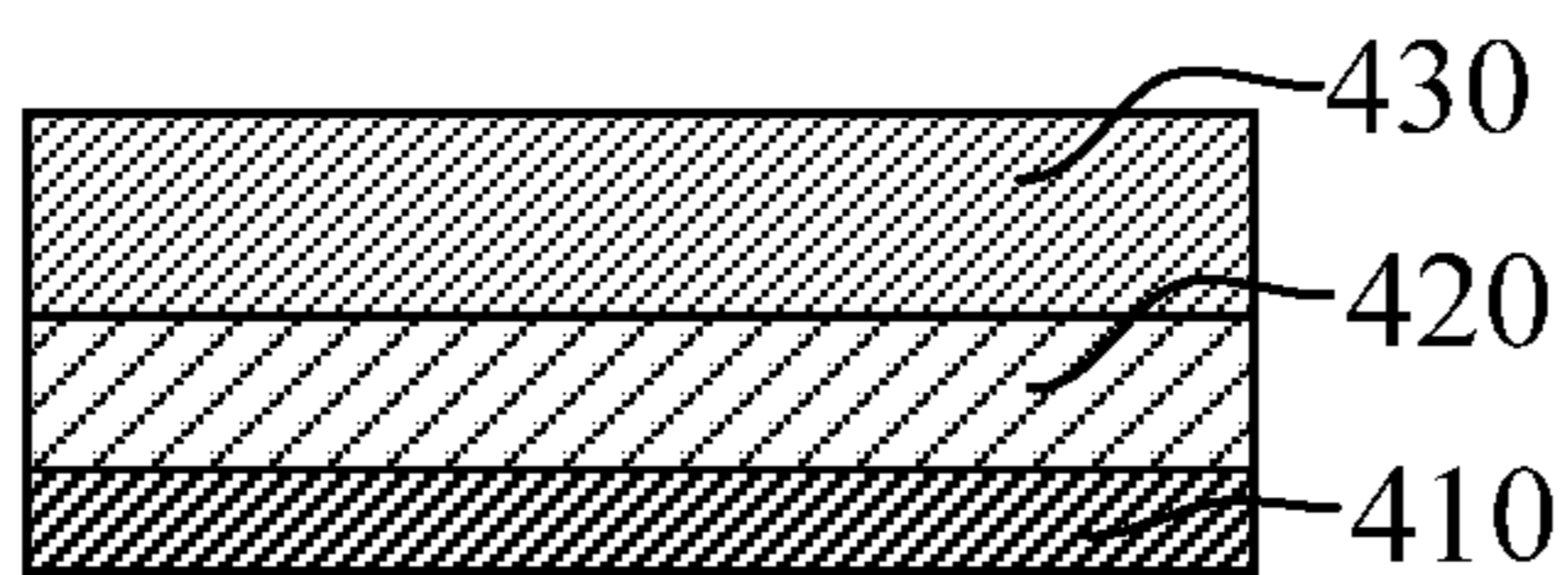


FIG. 4

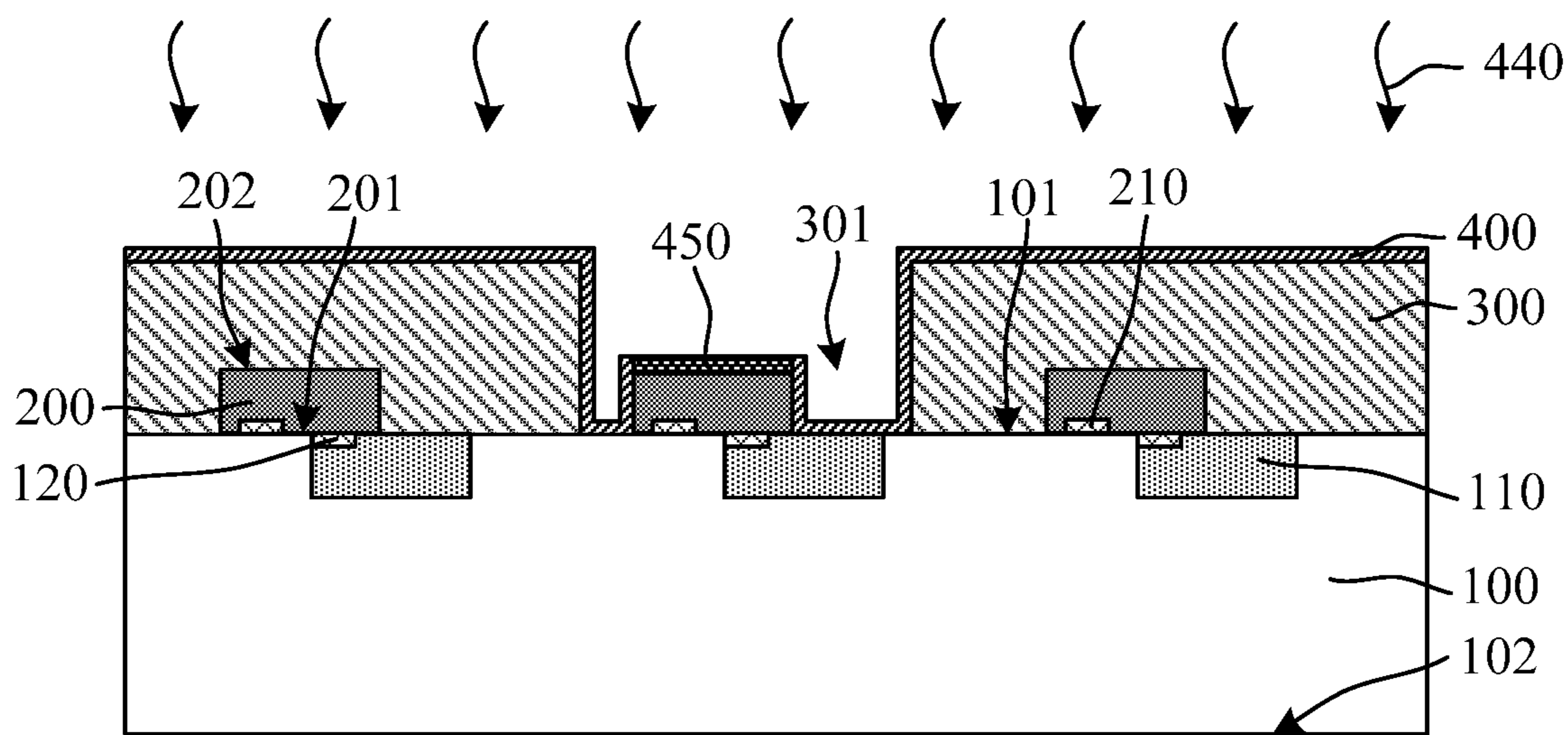


FIG. 5

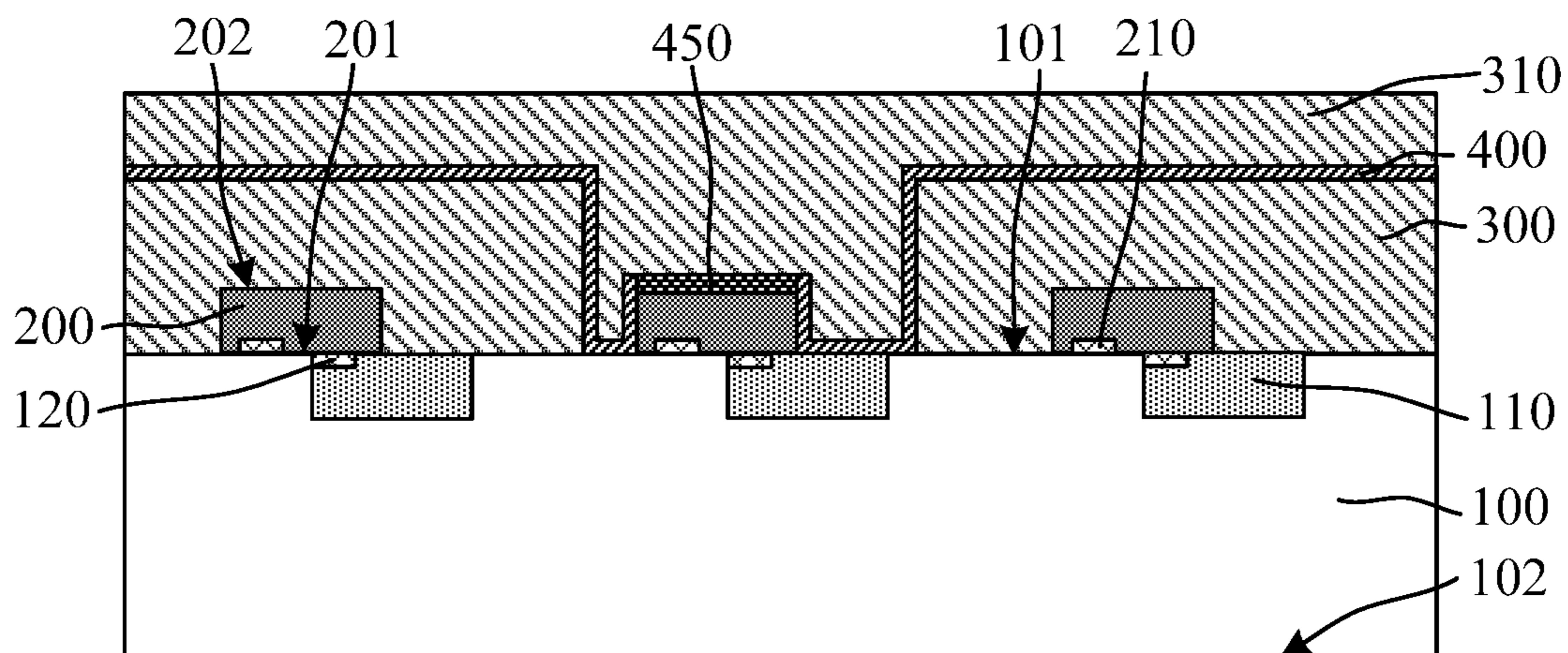


FIG. 6

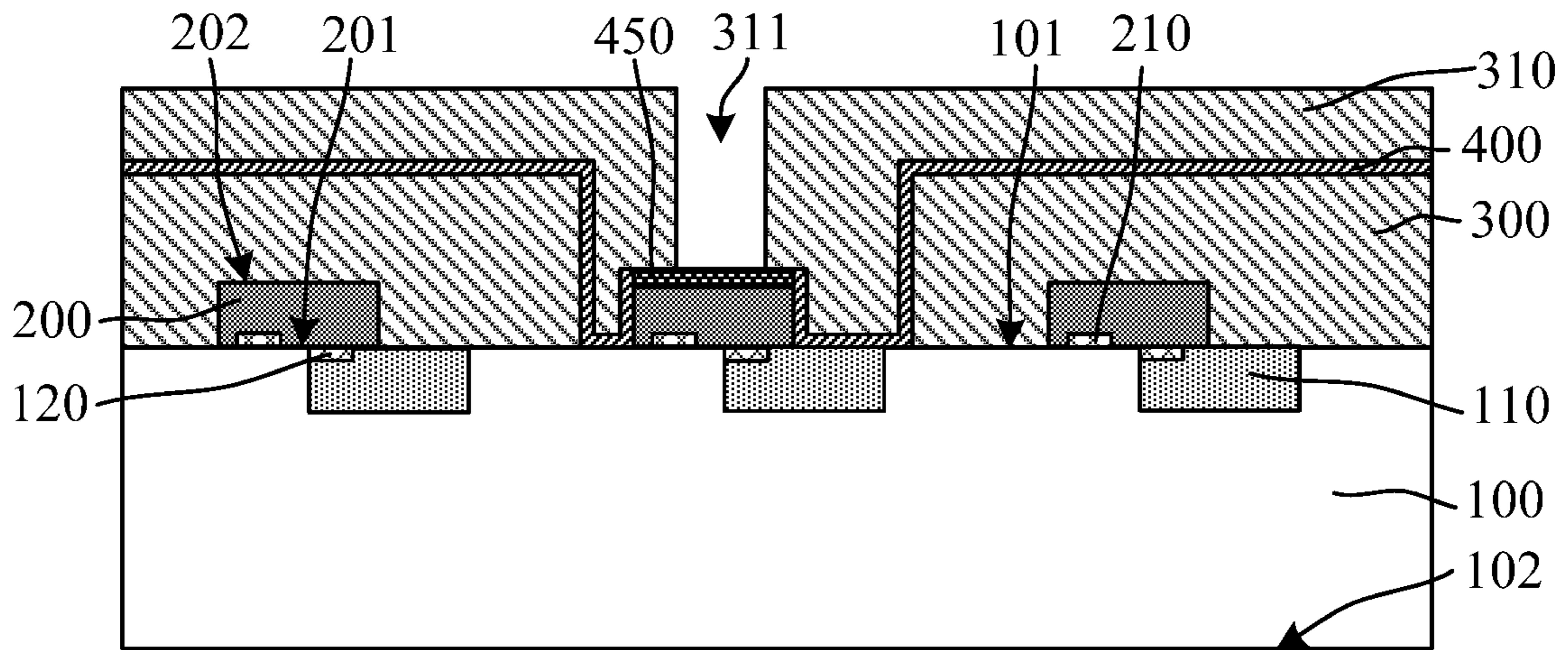


FIG. 7

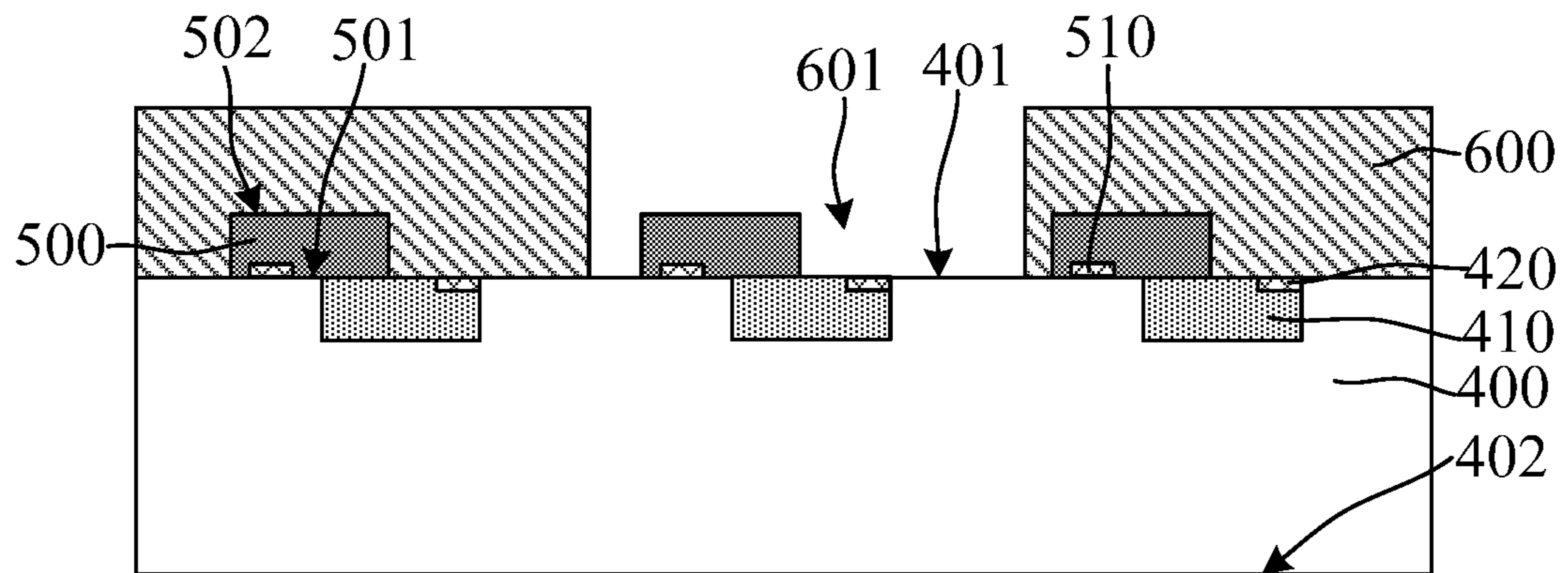


FIG. 8

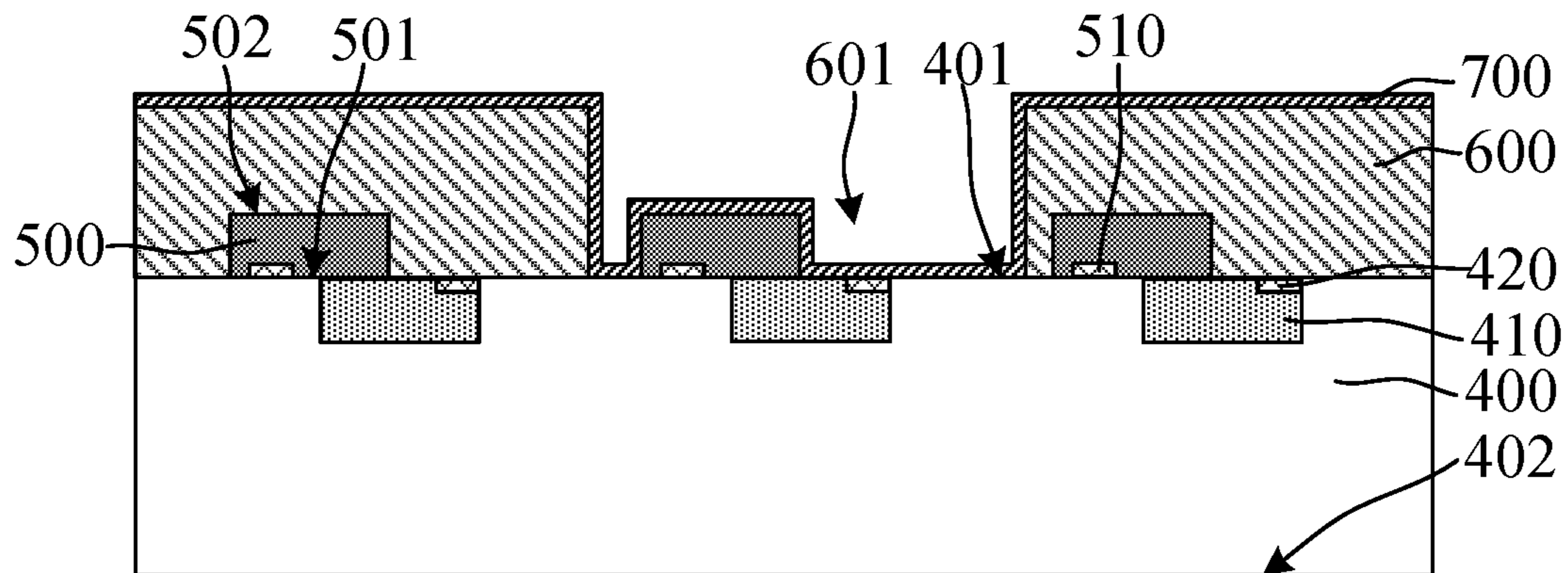


FIG. 9

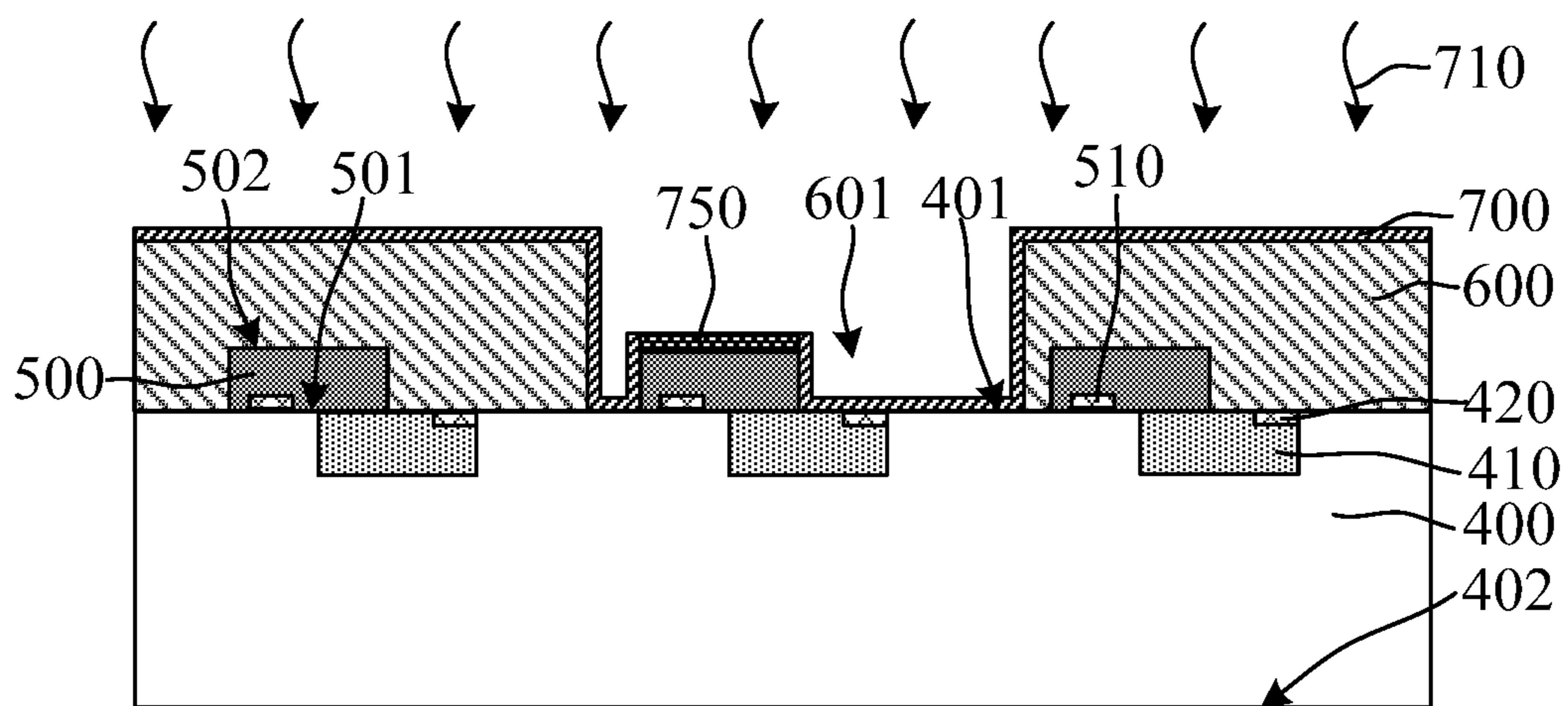


FIG. 10

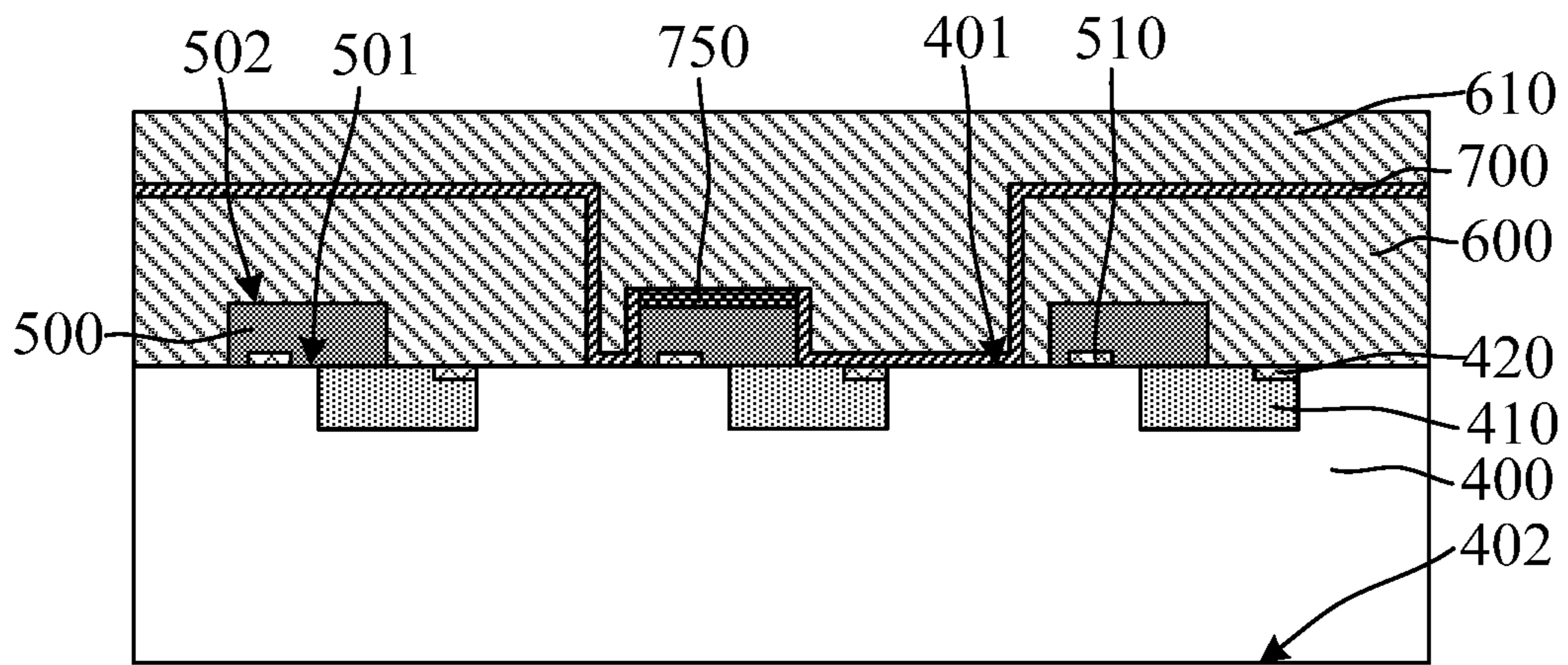


FIG. 11

WAFER-LEVEL PACKAGE STRUCTURE**CROSS-REFERENCES TO RELATED APPLICATION**

This application is a divisional of U.S. patent application Ser. No. 16/228,059, filed on Dec. 20, 2018, which is a continuation application of PCT Patent Application No. PCT/CN2018/113107, filed on Oct. 31, 2018, which claims priority to Chinese patent application No. 201811026716.3, filed on Sep. 4, 2018, the entirety of all of which is incorporated herein by reference.

TECHNICAL FIELD

The present disclosure generally relates to the field of semiconductor technologies and, more particularly, relates to a wafer-level package structure.

BACKGROUND

With the development of ultra-large-scale integrated circuits, the feature size of integrated circuits continues to decrease and requirements for packaging technologies of integrated circuits are increasing correspondingly. Conventional packaging technologies include ball grid array package (BGA), chip scale package (CSP), wafer level package (WLP), three-dimensional (3D) package and system-in-package (SiP), etc.

At present, in order to meet the goal of low cost, high reliability, fast package and high density of integrated circuit packaging, advanced packaging methods mainly use wafer-level system-in-package (WLSiP). Comparing with conventional system-in-package, wafer-level system-in-package, a packaging integration process is completed on wafers, which has advantages including greatly reducing the area of package structures, reducing manufacturing costs, optimizing electrical performance and performing batch manufacturing, etc. This may significantly reduce workload and equipment requirements.

SUMMARY

One aspect of the present disclosure includes a wafer-level packaging method. The method includes: providing a device wafer and a plurality of first chips bonded to the device wafer, where a first encapsulation layer covering the first chips is on the device wafer, the first chip of the plurality of first chips includes a chip front surface with a formed first pad and a chip back surface opposite to the chip front surface, and the chip front surface faces the device wafer; etching the first encapsulation layer to form a first opening exposing at least one first chip of the plurality of first chips in the first encapsulation layer, where the chip back surface exposed by the first opening is used for receiving a loading signal; forming a metal layer structure covering the at least one first chip exposed by the first opening, a bottom and sidewalls of the first opening and a top of the first encapsulation layer; performing an alloying treatment on the chip back surface of the at least one first chip and the metal layer structure, where a portion of the metal layer structure on the chip back surface becomes a back metal layer; and after the alloying treatment, forming a second encapsulation layer covering the back metal layer in the first opening, where the second encapsulation layer further covers a remaining portion of the metal layer structure on the top of the first encapsulation layer.

Another aspect of the present disclosure includes a wafer-level package structure. The structure includes: a device wafer; a plurality of first chips, bonded to the device wafer, where the first chip of the plurality of first chips includes a chip front surface with a formed first pad and a chip back surface opposite to the chip front surface, and the chip front surface faces the device wafer; a first encapsulation layer, formed on the device wafer and covering the first chips, where the first encapsulation layer has a first opening exposing at least one first chip of the plurality of first chips and the chip back surface exposed by the first opening is connected to a loading signal; a metal layer structure, covering the at least one first chip exposed by the first opening, a bottom and sidewalls of the first opening and a top of the first encapsulation layer, where the metal layer structure includes a back metal layer alloyed with the chip back surface by an alloying treatment between the chip back surface and a portion of the metal layer structure on the chip back surface; and a second encapsulation layer, formed in the first opening, covering the back metal layer, and further covering the metal layer structure on the top of the first encapsulation layer.

Other aspects or embodiments of the present disclosure can be understood by those skilled in the art in light of the description, the claims, and the drawings of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings are merely examples for illustrative purposes according to various disclosed embodiments and are not intended to limit the scope of the present disclosure.

FIGS. 1-7 illustrate structural schematics corresponding to structures at certain stages of an exemplary wafer-level packaging method according to various disclosed embodiments of the present disclosure; and

FIGS. 8-11 illustrate structural schematics corresponding to structures at certain stages of another exemplary wafer-level packaging method according to various disclosed embodiments of the present disclosure.

DETAILED DESCRIPTION

Reference will now be made in detail to exemplary embodiments of the disclosure, which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

The wafer-level packaging structures mainly include a device wafer and a plurality of chips bonded to the device wafer, and further include an encapsulation layer which is on the device wafer and covers the chips. The encapsulation layer covers the chips. Therefore, in the wafer-level packaging structures, it is difficult to load a signal (for example, a ground signal or a voltage signal) to a back surface of the chips.

The present disclosure provides a wafer-level packaging method and a wafer-level package structure, which may improve the performance of the wafer-level package structures.

An exemplary wafer-level packaging method may include: after etching a first encapsulation layer to expose a chip back surface of a first chip which is used for a loading signal, forming a metal layer structure covering the first chip exposed by the first opening, a bottom and sidewalls of the first opening and a top of the first encapsulation layer;

performing an alloying treatment on the chip back surface and the metal layer structure where the metal layer structure on the chip back surface is used as a back metal layer; and forming a second encapsulation layer covering the back metal layer. The back metal layer may be used as a back electrode of the first chip, which may load a signal (for example a ground signal) on the chip back surface suitable for loading signals according to actual process requirements, and may further improve the performance of wafer-level packaging structures.

To more clearly describe the objectives, features and advantages of the present disclosure, the present disclosure is further illustrated in detail with reference to the accompanying drawings in conjunction with embodiments.

FIGS. 1-7 illustrate structural schematics corresponding to structures at certain stages of an exemplary wafer-level packaging method according to various disclosed embodiments of the present disclosure.

Referring to FIG. 1, a complimentary metal-oxide-semiconductor (CMOS) device wafer and a plurality of first chips **200** bonded to the device wafer may be provided. The device wafer **100** may have a first encapsulation layer **300** covering the first chips **200**. The first chip **200** may include a first chip front surface **201** with a formed first pad **210** and a first chip back surface **202** opposite to the first chip front surface **201**, where the first chip front surface **201** may face the device wafer **100**.

In one embodiment, the wafer-level packaging method may be used to implement the wafer-level system-in-package. The device wafer **100** may be the wafer for a device completion. The device wafer **100** may be fabricated using an integrated circuit fabrication technology. For example, a device including an n-channel metal-oxide-semiconductor (NMOS) device or a p-channel metal-oxide-semiconductor (PMOS) device may be formed on a semiconductor substrate using a process including deposition and etching etc., where structures including a dielectric layer, a metal interconnection structure and a pad electrically connected to the metal interconnection structure may be formed on the device.

In one embodiment, a plurality of second chips **110** may be integrated in the device wafer **100** and a second pad **120** may be formed in the second chip **110**, where the plurality of the second chips **110** may be the same type or different types of chips.

In one embodiment, the second pad **120** may be a bond pad of the device wafer **100** and may be used to implement an electrical connection between the second chip **110** and other circuits.

It should be noted that, in one embodiment, in order to facilitate illustrations, three second chips **110** integrated in the device wafer **100** are taken as an example for description, but the number of the second chips **110** is not limited to three.

In one embodiment, a semiconductor substrate of the device wafer **100** may be a silicon substrate. In other embodiments, the semiconductor substrate may be made of a material including germanium, silicon germanium, silicon carbide, gallium arsenide, indium gallium and/or any other suitable material(s). The semiconductor substrate may also be made of a material including a silicon substrate on an insulator, a germanium substrate on an insulator, and/or any other suitable material(s). The material of the semiconductor substrate may be a material suitable for process requirements or easy to integrate.

In one embodiment, the device wafer **100** may include a wafer front surface **101** exposing the second pad **120** and a

wafer back surface **102** opposite to the wafer front surface **101**. The plurality of the first chips **200** may be bonded to the wafer front surface **101** of the device wafer **100**. The wafer back surface **102** may refer to a bottom surface, which is away from the second pad **120**, of the semiconductor substrate in the device wafer **100**.

The first chips **200** may be the chips to-be-integrated and the first chips **200** may be one or more components including active components, passive components, microelectron-mechanical systems, and optical components. For example, the first chips **200** may be memory chips, communication chips, processing chips, flash chips or logic chips. In other embodiments, the first chips may also be other functional chips.

In one embodiment, the wafer-level packaging method may be used to combine the plurality of the first chips **200** of different functions into one packaging structure, so the plurality of the first chips **200** may be obtained by cutting a plurality of wafers of different functional types. In other embodiments, the functional types of the plurality of the first chips may be the same according to actual processing requirements.

It should be noted that, in one embodiment, the wafer-level packaging method may be used to implement heterogeneous integration, so the plurality of the first chips **200** may be chips made of silicon wafers. In other embodiments, the plurality of the first chips **200** may be also chips made of other suitable materials.

The first chips **200** may have the same number of the second chips **110**. The first chips **200** may have a one-to-one correspondence with the second chips **110** and may have preset relative positional relationship. In one embodiment, the projection of the first chip **200** on the device wafer **100** may partially overlap with the second chip **110**. In other embodiments, the first chip may also be aligned with the corresponding second chip, that is, the projection of the first chip on the device wafer may coincide with the second chip.

The first chips **200** may be fabricated using an integrated circuit fabrication technology. The first chip **200** may generally include an NMOS device or a PMOS device formed on a semiconductor substrate, and may further include structures including a dielectric layer, a metal interconnection structure and a pad.

The first pad **210** may be formed in the first chip **200**. The first chip front surface **201** of the first chip **200** may expose the first pad **210** and the first pad **210** may be used to implement an electrical connection between the first chip **200** and other circuits. In one embodiment, the first pad may be a bond pad.

In one embodiment, the step of providing the device wafer **100** and the plurality of the first chips **200** bonded to the device wafer **100** may include: bonding the first chips **200** to the device wafer **100** using a fusion bonding process.

The fusion bonding may be a process that primarily uses interface chemical force to complete the bonding. Using the fusion bonding process, the first chip front surface **201** and the wafer back surface **101** may be bonded by covalent bonding, so the bonding strength between the device wafer **100** and the first chips **200** may be relatively high, which may improve the packaging yield. In other embodiments, the device wafer and the first chips may be bonded by other bonding methods such as adhesive bonding and glass dielectric bonding.

The first encapsulation layer **300** may cover the first chips **200** and the wafer front surfaces **101** of the device wafer **100**, which may be used for sealing and moisture proof. The first encapsulation layer **300** may protect the first chips **200** and the second chips **110**, so it may reduce a probability of

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the first chips **200** and the second chips **110** being damaged, contaminated or oxidized, which may facilitate optimizing of the performance of the obtained wafer-level packaging structure.

In one embodiment, the first encapsulation layer **300** may be made of epoxy resin (Epoxy). Epoxy resin has advantages of low shrinkage, good adhesion, good corrosion resistance, excellent electrical properties and low cost, and is widely used a packaging material for electronic devices and integrated circuits. In other embodiments, the first encapsulation layer may be made of a thermosetting material including polyimide or silica gel.

In one embodiment, the first encapsulation layer **300** may be formed by an injection molding process. The injection molding process may have good filling performance, so that the first encapsulation layer **300** may be better filled between the plurality of the first chips **200** and have a good packaging on the first chips **200** and the second chips **110**.

For example, the first encapsulation layer **300** may be formed by liquid molding compounds or solid molding compounds by the injection molding process. The first encapsulation layer **300** may have a wafer shape, and a diameter of the wafer-shaped encapsulation layer **300** may be the same as a diameter of the device wafer **100**. In other embodiments, the first encapsulation layer may be other suitable shapes and may be formed by other packaging processes.

Referring to FIG. 2, the first encapsulation layer **300** may be etched. A first opening **301** exposing at least one first chip **200** may be formed in the first encapsulation layer **300** and the first chip back surface **202** exposed by the first opening **301** may be used for receiving one or more loading signals.

By exposing the first chip back surface **202** for loading signals, a process basis may be provided for subsequent formation of the back metal layer on the first chip back surface **202**, where the back metal layer may be used as a back electrode of the first chip **200** which is used for receiving the loading signal.

It should be noted that, in order to reduce the process difficulty of etching the first encapsulation layer **300**, the bottom of the first opening **301** may expose a portion of the device wafer **100**, so that the wafer front surface **101** may be used as a stop position.

In one embodiment, the loading signal may be a ground signal, that is, the back metal layer subsequently formed on the first chip back surface **202** may be connected to a ground end, so that the first opening **301** may not expose the second pad **120** of the second chip **110** to avoid affecting the second chip **100** corresponding to the first chip **200**.

For example, the first encapsulation layer **300** may be etched by a laser etching process.

The laser etching process may use a high-energy laser beam to irradiate a surface of a workpiece to-be-etched, which may melt, vaporize the workpiece surface to form a trench with a certain depth to achieve the purpose of etching. The laser etching process may achieve one-time forming technology with different angles and patterns, without using a mask plate. The laser etching process may have features including high etching yield rate, high stability, good flexibility, no supplies, simple operation, no contact, no pollution, high precision and low cost etc. Using the laser etching process, a size of the first opening **301** may be controlled precisely and the topography quality of the first opening **301** may be improved, which may reduce the probability that the adjacent first chips **200** or second chips **110** may be exposed.

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In other embodiments, the process of etching the first encapsulation layer may also be a plasma etching process or a reactive ion etching process.

Referring to FIG. 3 and FIG. 4, FIG. 4 may be an enlarged view of the metal layer structure in the broken line box A in FIG. 3, and the metal layer structure **400** may be formed by covering the first chip **200** exposed by the first opening **301**, a bottom and sidewalls of the first opening **301** and a top of the first encapsulation layer **300**.

After a subsequent alloying treatment, the metal layer structure **400** on the first chip back surface **202** may become a back metal layer, which may be an electrode for loading ground signals.

In order to improve the performance of the subsequent metal layer and reduce the adverse effect on the first chip **200**, the metal layer structure **400** may have low contact resistance and thermal resistance, low thermal stress and high reliability. Furthermore, in order to ensure excellent electrical performance, the metal layer structure **400** may have excellent conductive property and may be capable of forming an ohmic contact with the first chip back surface **202**.

In one embodiment, the metal layer structure **400** may be a multiple-layered metal structure, so that the properties of different metals may be utilized to make subsequently formed electrodes meet process requirements.

For example, the metal layer structure **400** may include a bottom metal layer **410**, a transition metal layer **420** on the bottom metal layer, and a top metal layer **430** on the transition metal layer.

The material of the bottom metal layer **410** may be a low potential barrier material and the contact resistance with the first chip back surface **202** may be relatively small. The material of the bottom metal layer **410** and the material of the first chip back surface **202** may have good formed alloy properties, which may be used as an ohmic contact layer.

In one embodiment, the material of the bottom metal layer **410** may be Ti. Ti and the material of the first chip back surface **202** may have good formed alloy properties, which may form an ohmic contact easily and also may have low process difficulty to form relatively high purity Ti. Therefore, selecting Ti as the material of the bottom metal layer **410** may also lower the process difficulty to form the metal layer structure **400**. Furthermore, the chemical and mechanical properties of Ti may be relatively stable and the material of the first chip back surface **202** may have a good thermal matching with Ti, which may significantly improve the performance and reliability of the wafer-level packaging structure.

In other embodiments, the bottom metal layer may also be made of a material including Cr, Al or V.

The greater the thickness of the bottom metal layer **410**, the greater the resistance of the bottom metal layer **410**. Therefore, the thickness of the bottom metal layer **410** may not be too large, otherwise the performance and reliability of the wafer-level packaging structure may be reduced easily and process resources may be wasted. However, the thickness of the bottom metal layer **410** may not be too small. If the thickness of the bottom metal layer **410** is too small, the effect of the subsequent alloying treatment may be reduced easily, and the performance and reliability of the wafer-level packaging structure may also be reduced accordingly. In one embodiment, the thickness of the bottom metal layer **410** may be of about 1000 Å to 5000 Å.

The top metal layer **430** may have features of low resistivity, strong anti-electromigration performance, stable performance and difficulty in oxidation etc., so the top metal

layer may function as a conductive layer, may protect the transition metal layer **420** and reduce the oxidation probability of the transition metal layer **420**.

In one embodiment, the material of the top metal layer **430** may be Ag. Ag may be a material which is commonly used in the process and has a low cost. Therefore, Ag may be selected as the material of the top metal layer **430**, which may reduce the process difficulty and process cost. In other embodiments, the material of the top metal layer may also be Au.

The thickness of the top metal layer **430** may be relatively large, which may effectively improve the protection on the transition metal layer **420** and may improve the reliability of the back metal layer when a ground signal is loaded on the subsequently formed back metal layer, so the performance stability of the wafer-level packaging structure may be improved; however, the thickness of the top metal layer **430** may not be too large. If the thickness of the top metal layer **430** is too large, the resistance of the top metal layer **430** may be too large, which may reduce the performance and reliability of the wafer-level packaging structure and may waste process resources. In one embodiment, the thickness of the top metal layer **430** may be of about 1000 Å to about 50000 Å.

The transition metal layer **420** may block the diffusion of the material of the top metal layer **430** into the bottom metal layer **410**, and the expansion coefficient of the transition metal layer **420** may be between the expansion coefficients of the top metal layer **430** and the bottom metal layer **410**. The transition metal layer may have moderate electrical conductivity and thermal conductivity, which may achieve a good thermal matching. In addition, the transition metal layer **420** may have good adhesion with the bottom metal layer **410** and the top metal layer **430**, which may have the advantage of the improvement of the formation quality of the metal layer structure **400** and the reduced probability of falling off between the metal layers. In one embodiment, the material of the transition metal layer **420** may be Ni.

Correspondingly, in order to perform an excellent thermal matching and blocking effect of the transition metal layer **420**, the thickness of the transition metal layer **420** may be greater than the thickness of the bottom metal layer **410** and the thickness of the transition metal layer **420** may be less than the thickness of the top metal layer **430**. In one embodiment, according to the thicknesses of the bottom metal layer **410** and the top metal layer **430**, the thickness of the transition metal layer **420** may be of about 1000 Å to about 5000 Å.

Each of the bottom metal layer **410**, the transition metal layer **420** and the top metal layer **430** may be formed by one of an electroplating process, a physical gas deposition process and an electron beam evaporation process. In order to improve the performance of the metal layer structure **400**, the formation processes of the bottom metal layer **410**, the transition metal layer **420** and the top metal layer **430** may be the same, which may ensure good quality and topography and may better control the thickness of each metal layer.

In one embodiment, the bottom metal layer, the transition metal layer and the top metal layer may be formed using the electroplating process, which may improve adhesion and mechanical strength of each metal layer. Correspondingly, the metal layer structure **400** may conformally cover the first chip **200**, the bottom and sidewalls of the first opening **301** and the top of the first encapsulation layer **300**. In other embodiments, the metal layer structure may also be filled in the first opening.

Referring to FIG. 5, the first chip back surface **202** and the metal layer structure **400** may perform an alloying treatment **440**, and the metal layer structure **400** of the first chip back surface **202** may become a back metal layer **450**.

The back metal layer **450** may be used as an electrode for loading ground signals. Its resistance of the first chip **200** and a contact resistance of the electrode may be reduced by using the alloying treatment **440**, and a ground resistance may be reduced correspondingly, which may reduce the loss of electrical energy and improve the performance and reliability of the wafer-level packaging structure.

In one embodiment, the alloying treatment **440** may be an annealing process. At the temperature of the annealing process, the bottom metal layer **410** (shown in FIG. 4) and the material of the first chip back surface **202** may mutually diffuse and react with each other at the contact surface, and achieve alloying at the contact surface.

For example, the material of the bottom back metal layer **410** may be Ti. The semiconductor substrate of the first chip **200** may be a silicon substrate. Correspondingly, after the alloying treatment **440**, a TiSi alloy may be formed at the contact surface to form an ohmic contact.

In one embodiment, after the alloying treatment **440**, the metal layer structure **400** of the first chip back surface **202** may become the back metal layer **450**.

The processing temperature of the alloying treatment **440** may be not too low or not too high. If the processing temperature is too low, an alloying rate between the bottom metal layer **410** and the first chip back surface **202** may be slow, which may be disadvantageous to reduce contact resistance and may easily reduce the performance of the wafer-level packaging structure; and if the processing temperature is too high, it may adversely affect the performance of devices in the first chips **200** and the second chips **110**, and may also easily reduce the performance of the wafer-level packaging structure. In one embodiment, the processing temperature of the alloying treatment **440** may be of about 100° C. to about 250° C.

The processing time of the alloying treatment **440** may be not too short or not too long. If the processing time is too short, it may be difficult to provide sufficient time for the alloying at the contact surface of the bottom metal layer **410** and the first chip back surface **202**, which may be disadvantageous to reduce contact resistance and may easily reduce the performance of the wafer-level packaging structure; and if the processing time is too long, it may increase the thermal budget and decrease the efficiency accordingly, and also may adversely affect the performance of devices in the first chips **200** and the second chips **110**. In one embodiment, the processing time of the alloying treatment **440** may be of about 30 min to about 160 min.

In one embodiment, by appropriately setting the process parameters of the alloying treatment **440** and coordinating the processing temperature and the processing time, the efficiency of the alloying treatment may be improved and the probability of negative effects may be reduced when the alloying is achieved efficiently.

It should be noted that, in one embodiment, the firstly formed metal layer structure **400** and the subsequently performed alloying treatment **440** may be used as an example for description. In other embodiments, in the step of forming the metal layer structure on the chip back surface exposed by the first opening, the metal layer structure may be a single metal layer. In one embodiment, the single metal layer may be substantially same as the above described bottom metal layer. Correspondingly, after the alloying treatment, the method may further include: forming the

transition metal layer on the bottom metal layer, forming the top metal layer on the transition metal layer, and using the top metal layer, the transition metal layer and the bottom metal layer with the alloying treatment as the back metal layer.

By performing the alloying treatment before the formation of the transition metal layer and the top metal layer, it may be advantageous to reduce the difficulty of the alloying treatment, which may implement the alloying treatment efficiently and significantly.

Referring to FIG. 6, after the alloying treatment 440 (shown in FIG. 5), a second encapsulation layer 310 covering the back metal layer 450 may be formed in the first opening 301 (shown in FIG. 5). The second encapsulation layer 310 may also cover the metal layer structure 400 on the top of the first encapsulation layer 300.

The second encapsulation layer 310 may be used to protect the metal layer structure 400 which is not alloyed and the back metal layer 450, which may prevent an external environment from affecting the metal layer structure 400 and the back metal layer 450, and further avoid an impact on the performance of the wafer-level packaging structure.

The detailed description of the second encapsulation layer 310 should refer to the above-mentioned corresponding description of the first encapsulation 300, which is not described herein.

It should be noted that, after forming the second encapsulation layer 310, the method may further include: thinning the device wafer 100 from the wafer back surface 102, and forming a silicon through hole interconnection structure in the device wafer 100 after the thinning treatment, which may be electrically connected to the second chip 110. In one embodiment, details may not be described herein.

Referring to FIG. 7, in one embodiment, after forming the second encapsulation layer 310, the method may further include: etching the second encapsulation layer 310, and forming a second opening 311 exposing the back metal layer 450 in the second encapsulation layer 310.

After forming the second opening 311, the second opening 311 may expose the back metal layer 450, which may achieve electrical connections between the back metal layer 450 and other circuits.

In one embodiment, the second opening 311 may expose a portion surface of the back metal layer 450. In other embodiments, according to the actual process, the second opening may expose the entire surface of the back metal layer.

In one embodiment, the second encapsulation layer 310 may be etched by a laser etching process. In other embodiments, the second encapsulation layer may be etched by a plasma etching process or a reactive ion etching process.

The detailed process description for etching the second encapsulation layer 310 may refer to the corresponding above-mentioned process description for etching the first encapsulation layer 300, and details may be not described herein.

FIGS. 8-11 illustrate structural schematics corresponding to structures at certain stages of another exemplary wafer-level packaging method according to various disclosed embodiments of the present disclosure.

The similarity between the present embodiment and the previous embodiment may be not described herein. The difference between the present embodiment and the previous embodiment is: a loading signal may be a voltage signal.

Correspondingly, referring to FIG. 8, after etching an first encapsulation layer 600, an opening 601 may be formed in

the first encapsulation layer 600, and the opening 601 may expose a second pad 420 of a second chip 410.

Exposing the second pad 420 may provide a process basis for the subsequent electrical connection between the first chip back surface 502 of a first chip 500 and the second pad 420.

For example, forming the opening 601 may include: providing a device wafer 400 and a plurality of first chips 500 bonded to the device wafer 400; forming the first encapsulation layer 600 covering the first chips 500 on the device wafer 400, where the first chip 500 may include a first chip front surface 501 with a formed pad 510 and a first chip back surface 502 opposite to the first chip front surface 501, and the first chip front surface 501 may face the device wafer 400; etching the first encapsulation layer 600 and forming the opening 601, exposing at least one first chip 500, in the first encapsulation layer 600; and exposing the second pad 420 of the second chip 410 corresponding to the first chip 500 by the opening 601, where the first chip back surface 502 exposed by the opening 601 may be used for loading a voltage signal.

In one embodiment, the first chips 500 may be bonded to the device wafer 400 by a fusion bonding process, so that it may improve a bonding strength between the device wafer 400 and the first chips 500, which may be advantageous to improve the packaging yield and the performance of the wafer-level packaging structure correspondingly.

In one embodiment, the device wafer 400 may include a wafer front surface 401 exposing the second pad 420 and a wafer back surface 402 opposite to the wafer front surface 401, and the plurality of the first chips 500 may be bonded to the wafer front surface 401 of the device wafer 400.

It should be noted that, in the process of forming the device wafer 400, the wafer front surface 401 may expose the second pad 420 and a position of the second pad 420 on the second chip 410 may be determined by a position of the first chip 500 on the wafer front surface 401, so that the first chip 500 may expose the second pad 420 after the first chip 500 is bonded to the device wafer 400. Correspondingly, after forming the opening 601 in the first encapsulation layer 600, the opening 601 may expose the second pad 420, which may reduce the process difficulty of exposing the second pad 420.

The detailed description of the device wafer 400, the first chips 500, the first encapsulation layer 600 and the opening 601 may refer to the corresponding description in above-mentioned embodiment. Details may not be described herein.

Referring to FIG. 9, a metal layer structure 700 may be formed by covering the first chip 500 exposed by the opening 601, a bottom and sidewalls of the opening 601 and a top of the first encapsulation layer 600.

In one embodiment, the first chip back surface 502 of the first chip 500 may be used for receiving a loading voltage, so the first chip back surface 502 may be suitable for connecting to the second pad 420 electrically, which may apply voltages to the first chip back surface 502 through the second pad 420.

Correspondingly, during the formation of the metal layer structure 700, the metal layer structure 700 may be further formed on the surface of the second pad 420. The metal layer structure 700 may be connected to the second pad 420 electrically, so the first chip back surface 502 and the second pad 420 may be electrically connected through the metal layer structure 700.

In one embodiment, the metal layer structure 700 may be formed by an electroplating process. Correspondingly, the

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metal layer structure **700** may conformally cover the first chips **500**, the bottom and sidewalls of the opening **601** and the top of the first encapsulation layer **600**.

The detailed description of the metal layer structure **700** may refer to the corresponding description in the above-mentioned embodiment. Details may be not described herein.

Referring to FIG. **10** and FIG. **11**, the first chip back surface **502** and the metal layer structure **700** may perform an alloying treatment **710** (shown in FIG. **10**), and the metal layer structure **700** of the first chip back surface **502** may become a back metal layer **750** (shown in FIG. **10**); after the alloying treatment **710**, a second encapsulation layer **610** (shown in FIG. **11**) covering the back metal layer **750** may be formed in the opening **601**. The second encapsulation layer **610** may also cover the metal layer structure **700** on the top of the first encapsulation layer **600**.

After the alloying treatment **710**, a bottom metal layer (not shown) of the metal layer structure **700** and the material of the first chip back surface **502** may mutually diffuse and react each other at a contact surface to form an ohmic contact.

The second encapsulation layer **610** may cover the metal layer structure **700** which is not alloyed and the back metal layer **750**. The metal layer structure **700** may be connected to the second pad **420** electrically, so the first chip back surface **502** and external circuits may be connected electrically through the electrical connection between the second pad **420** and external circuits, and voltage signals may be loaded on the first chip back surface **502**.

The detailed description of the alloying treatment **710** and the second encapsulation layer **610** may refer to the corresponding description in the above-mentioned embodiment. Details may be not described herein.

Correspondingly, the present disclosure may provide a wafer-level packaging structure. Referring to FIG. **7**, it illustrates a structural schematic of an exemplary wafer-level packaging structure of the present disclosure.

The wafer-level packaging structure may include: the device wafer **100**; the plurality of first chips **200** bonded to the device wafer **100**, where the first chip **200** may include the first chip front surface **201** with the formed first pad **210** and the first chip back surface **202** opposite to the first chip front surface **201**, and the first chip front surface **201** may face the device wafer **100**; the first encapsulation layer **300** which is on the device wafer **100** and covers the first chips **200**, where the first opening **301** (shown in FIG. **5**) exposing at least one first chip **200** may be formed in the first encapsulation layer **300** and the first chip back surface **202** exposed by the first opening **301** may be used for receiving a loading signal; the metal layer structure **400** covering the first chip **200** exposed by the first opening **301**, the bottom and sidewalls of the first opening **301** and the top of the first encapsulation layer **300**, where an alloying treatment may perform on the metal layer structure **400** of the first chip back surface **202** and the first chip back surface **202**, and the metal layer structure **400** of the first chip back surface **202** may become a back metal layer **450**; and a second encapsulation layer **310**, which may be in the first opening **301**, may cover the back metal layer **450**, and may further cover the metal layer structure **400** on the top of the first encapsulation layer **300**.

In one embodiment, the wafer-level packaging structure may be a wafer-level system-in-package packaging structure. The device wafer **100** may be integrated in the wafer-level packaging structure.

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The device wafer **100** may be the wafer for a device completion. The device wafer **100** may be fabricated using an integrated circuit fabrication technology. For example, a device including an NMOS device or a PMOS device may be formed on a semiconductor substrate including a process including deposition and etching etc., and structures including a dielectric layer, a metal interconnection structure and a pad electrically connected to the metal interconnection structure may be formed on the device.

In one embodiment, the plurality of second chips **110** may be integrated in the device wafer **100** and the second pad **120** may be formed in the second chip **110**, where the plurality of the second chips **110** may be the same type or different types of chips.

In one embodiment, the second pad **120** may be a bond pad of the device wafer **100** and may be used to implement an electrical connection between the second chip **110** and other circuits.

It should be noted that, in one embodiment, in order to facilitate illustrations, three second chips **110** integrated in the device wafer **100** are taken as an example for description, but the number of the second chips **110** is not limited to three.

In one embodiment, the device wafer **100** may include a wafer front surface **101** exposing the second pad **120** and a wafer back surface **102** opposite to the wafer front surface **101**. The plurality of the first chips **200** may be bonded to the wafer front surface **101** of the device wafer **100**. The wafer back surface **102** may refer to a bottom surface, away from the second pad **120**, of the semiconductor substrate in the device wafer **100**.

The first chips **200** may be integrated in the wafer-level packaging structure. The first chips **200** may be one or more components including active components, passive components, microelectromechanical systems, and optical components. For example, the first chips **200** may be memory chips, communication chips, processing chips, flash chips or logic chips. In other embodiments, the first chips may also be other functional chips.

In one embodiment, the plurality of the first chips **200** may be obtained by cutting a plurality of wafers of different functional types. In other embodiments, the functional types of the plurality of the first chips may be the same according to actual processing requirements.

It should be noted that, in one embodiment, the wafer-level packaging method may be used to implement heterogeneous integration, so the plurality of the first chips **200** may be chips made of silicon wafers. In other embodiments, the plurality of the first chips **200** may be also chips made of other suitable materials.

The first chips **200** may have the same number of the second chips **110**. The first chips **200** may have a one-to-one correspondence with the second chips **110** and may have preset relative positional relationship. In one embodiment, the projection of the first chip **200** on the device wafer **100** may partially overlap with the second chip **110**.

In other embodiments, the first chip may also be aligned with the corresponding second chip, that is, the projection of the first chip on the device wafer may coincide with the second chip.

The first pad **210** may be formed in the first chip **200**. The first chip front surface **201** of the first chip **200** may expose the first pad **210** and the first pad **210** may be used to implement an electrical connection between the first chip **200** and other circuits. In one embodiment, the first pad may be a bond pad.

The first encapsulation layer **300** may cover the first chips **200** and the wafer front surfaces **101** of the device wafer **100**, which may be used for sealing and moisture proof. The first encapsulation layer **300** may protect the first chips **200** and the second chips **110**, so it may reduce a probability of the first chips **200** and the second chips **110** being damaged, contaminated or oxidized, which may facilitate optimizing of the performance of the obtained wafer-level packaging structure.

In one embodiment, the first encapsulation layer **300** may be made of epoxy resin (Epoxy). Epoxy resin has advantages of low shrinkage, good adhesion, good corrosion resistance, excellent electrical properties and low cost, and is widely used a packaging material for electronic devices and integrated circuits. In other embodiments, the first encapsulation layer may be made of a thermosetting material including polyimide or silica gel.

For example, the first encapsulation layer **300** may be formed by an injection molding process. The first encapsulation layer **300** may have a wafer shape, and a diameter of the wafer-shaped encapsulation layer **300** may be the same as a diameter of the device wafer **100**. In other embodiments, the first encapsulation layer may be other suitable shapes.

The first opening **301** may be formed in the first encapsulation layer **300** and may expose the first chip back surface **202** which may be used for receiving a loading signal, so that a position space for forming the back metal layer **450** may be provided. The first opening **301** may be formed by etching the first encapsulation layer **300**. In order to reduce the process difficulty of forming the first opening **301**, the bottom of the first opening **301** may expose the device wafer **100**, so that the wafer front surface **101** may be used as a stop position.

In one embodiment, the back metal layer **450** may be used as an electrode for loading ground signals. The back metal layer **450** may be formed by performing the alloying treatment on the first chip back surface **202** and the metal layer structure **400** of the first chip back surface **202**, so itself resistance of the first chip **200** and a contact resistance of the electrode may be small, and a ground resistance may be reduced correspondingly, which may reduce the loss of electrical energy and improve the performance and reliability of the wafer-level packaging structure.

In order to improve the performance of the back metal layer **450** and reduce the adverse effect on the first chip **200**, the metal layer structure **400** may have low contact resistance and thermal resistance, low thermal stress and high reliability. Furthermore, in order to ensure good electrical performance, the metal layer structure **400** may have good conductive performance and may be capable of forming an ohmic contact with the first chip back surface **202**.

In one embodiment, the metal layer structure **400** may be a multiple-layered metal structure, so that the properties of different metals may be utilized to make the back metal layer **450** meet process requirements.

FIG. 4 may be an enlarged view of the metal layer structure. The metal layer structure **400** may include a bottom metal layer **410**, a transition metal layer **420** on the bottom metal layer **410**, and a top metal layer **430** on the transition metal layer **420**.

The material of the bottom metal layer **410** may be a low potential barrier material and the contact resistance with the first chip back surface **202** may be small. The material of the bottom metal layer **410** and the material of the first chip back surface **202** may have good wettability, which may be used as an ohmic contact layer.

In one embodiment, the material of the bottom metal layer **410** may be Ti. Ti and the material of the first chip back surface **202** may have good wettability, which may form an ohmic contact easily and may have low process difficulty to form high purity Ti. Therefore, selecting Ti as the material of the bottom metal layer **410** may also lower the process difficulty to form the metal layer structure **400**. Furthermore, the chemical and mechanical properties of Ti may be relatively stable and the material of the first chip back surface **202** may have a good thermal matching with Ti, which may significantly improve the performance and reliability of the wafer-level packaging structure.

In other embodiments, the bottom metal layer may also be made of a material including Cr, Al, V, or a combination thereof.

The greater the thickness of the bottom metal layer **410**, the greater the resistance of the bottom metal layer **410**. Therefore, the thickness of the bottom metal layer **410** may not be too large, otherwise the performance and reliability of the wafer-level packaging structure may be reduced easily and process resources may be wasted. However, the thickness of the bottom metal layer **410** may not be too small. If the thickness of the bottom metal layer **410** is too small, the quality and the performance of the back metal layer **450** may be reduced, and the performance and reliability of the wafer-level packaging structure may be reduced correspondingly. In one embodiment, the thickness of the bottom metal layer **410** may be of about 1000 Å to 5000 Å.

The top metal layer **420** may have features of low resistivity, strong anti-electromigration performance, stable performance and difficulty in oxidation etc., so the top metal layer may function as a conductive layer, may protect the transition metal layer **420** and reduce the oxidation probability of the transition metal layer **420**.

In one embodiment, the material of the top metal layer **420** may be Ag. Ag may be a material which is commonly used in the process and has a low cost. Therefore, Ag may be selected as the material of the top metal layer **420**, which may reduce the process difficulty and process cost.

In other embodiments, the material of the top metal layer may also be Au.

The thickness of the top metal layer **430** may be relatively large, which may effectively improve the protection on the transition metal layer **420** and may improve the reliability of the back metal layer when a ground signal is loaded on the back metal layer **450**, so performance stability of the wafer-level packaging structure may be improved; however, the thickness of the top metal layer **430** may not be too large. If the thickness of the top metal layer **430** is too large, the resistance of the top metal layer **430** may be too large, which may reduce the performance and reliability of the wafer-level packaging structure and may waste process resources. In one embodiment, the thickness of the top metal layer **430** may be of about 1000 Å to about 50000 Å.

The transition metal layer **420** may block the diffusion of the material of the top metal layer **430** into the bottom metal layer **410**, and the expansion coefficient of the transition metal layer **420** may be between the expansion coefficients of the top metal layer **430** and the bottom metal layer **410**. The transition metal layer may have moderate electrical conductivity and thermal conductivity, which may achieve a good thermal matching. In addition, the transition metal layer **420** may have good adhesion with the bottom metal layer **410** and the top metal layer **430**, which may have the advantage of the improvement of the formation quality of the metal layer structure **400** and the reduced probability of

falling off between the metal layers. In one embodiment, the material of the transition metal layer **420** may be Ni.

Correspondingly, in order to perform a good thermal matching and blocking effect of the transition metal layer **420**, the thickness of the transition metal layer **420** may be greater than the thickness of the bottom metal layer **410** and the thickness of the transition metal layer **420** may be less than the thickness of the top metal layer **430**. In one embodiment, according to the thicknesses of the bottom metal layer **410** and the top metal layer **430**, the thickness of the transition metal layer **420** may be of about 1000 Å to about 5000 Å.

In one embodiment, the back metal layer **450** may be formed by performing the alloying treatment on the first chip back surface **202** and the metal layer structure **400** of the first chip back surface **202**, so the back metal layer **450** may also include a bottom metal layer **410**, a transition metal layer **420** on the bottom metal layer **410**, and a top metal layer **430** on the transition metal layer **420**, and the alloying treatment may be performed on the bottom metal layer **410** and the first chip back surface **202** and the contact surface between the bottom metal layer **410** and the first chip back surface **202** may contain an alloy (not shown).

For example, the material of the bottom back metal layer **410** may be Ti. The semiconductor substrate of the first chip **200** may be a silicon substrate. Correspondingly, the contact surface between the bottom metal layer **410** and the first chip back surface **202** may contain the TiSi alloy to form an ohmic contact.

In one embodiment, the metal layer structure **400** may conformally cover the first chip **200**, the bottom and sidewalls of the first opening **301** and the top of the first encapsulation layer **300**. In other embodiments, the metal layer structure may also be filled in the first opening.

The second encapsulation layer **310** may be used to protect the metal layer structure **400** and the back metal layer **450**, which may prevent an external environment from affecting the metal layer structure **400** and the back metal layer **450** and further avoid an impact on the performance of the wafer-level packaging structure.

In one embodiment, the first chip back surface **202** exposed by the first opening **301** may be used for receiving a loading ground signal. The wafer-level packaging structure may further include: the second opening **311**, exposing the back metal layer **450**, in the second encapsulation layer **310**.

The electrical connection between the back metal layer **450** and other circuits may be achieved through exposing the back metal layer **450** by the second opening **311**.

In one embodiment, the second opening **311** may expose a portion surface of the back metal layer **450**. In other embodiments, according to the actual process, the second opening may expose the entire surface of the back metal layer.

The detailed description of the second encapsulation layer **310** may refer to the corresponding above-mentioned description of the first encapsulation layer **300**, and details may be not described herein.

It should be noted that, in one embodiment, the device wafer **100** may be the wafer after the thinning treatment, and the device wafer **100** after the thinning treatment may have the formed silicon through hole interconnection structure (not shown), which may be electrically connected to the second chip **110**. In one embodiment, details may not be described herein.

In one embodiment, the wafer-level packaging structure may be formed using the wafer-level packaging method described in the first embodiment or may be formed using

other packaging methods. In one embodiment, the detailed description of the wafer-level packaging structure may refer to the corresponding description in the above-mentioned embodiments, and details may be not described herein.

FIG. **11** illustrates a structural schematic of another exemplary wafer-level packaging structure of the present disclosure.

The similarity between the present embodiment and the previous embodiment may be not described herein. The difference between the present embodiment and the previous embodiment is: a loading signal may be a voltage signal.

Correspondingly, the opening **601** (shown in FIG. **10**) in the first encapsulation layer **600** may expose the second pad **420**, and the metal layer structure **700** may on the surface of the second pad **420**.

The metal layer structure **700** and the second pad **420** may be connected electrically, so the first chip back surface **502** and the second pad **420** may be electrically connected through the metal layer structure **700**, and voltages may be loaded on the back metal layer **700** through the second pad **420** and may be loaded on the first chip back surface **502**.

In one embodiment, the wafer-level packaging structure may be formed using the wafer-level packaging method described in the second embodiment or may be formed using other packaging methods. In one embodiment, the detailed description of the wafer-level packaging structure may refer to the corresponding description in the above-mentioned embodiments, and details may be not described herein.

In the present disclosure, the wafer-level packaging method may include: after etching a first encapsulation layer to expose a chip back surface of a first chip which is used for receiving a loading signal, forming a metal layer structure covering the first chip exposed by the first opening, a bottom and sidewalls of the first opening and a top of the first encapsulation layer; performing an alloying treatment on the chip back surface and the metal layer structure where the metal layer structure on the chip back surface is used as a back metal layer; and forming a second encapsulation layer covering the back metal layer. The back metal layer may be used as a back electrode of the first chip, which may load a signal (for example a ground signal) on the chip back surface suitable for receiving the loading signals according to actual process requirements, and may further improve the performance of wafer-level packaging structures.

Optionally or additionally, in the present disclosure, a plurality of second chips are formed in the device wafer and a second pad is formed on a surface of the second chip of the plurality of second chips facing the first chip; after etching the first encapsulation layer, the first opening exposes the second pad and the metal layer structure is also formed on a surface of the second pad. The electrical connection between the chip back surface of the first chip and the second chip may be achieved by the metal layer structure and the back metal layer, so a voltage signal may be applied to the chip back surface through the second chip.

The embodiments disclosed herein are exemplary only. Other applications, advantages, alternations, modifications, or equivalents to the disclosed embodiments are obvious to those skilled in the art and are intended to be encompassed within the scope of the present disclosure.

What is claimed is:

1. The wafer-level packaging structure, comprising:
 - a device wafer;
 - a plurality of first chips, bonded to the device wafer, wherein the first chip of the plurality of first chips includes a chip front surface with a formed first pad and

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- a chip back surface opposite to the chip front surface, and the chip front surface faces the device wafer;
- a first encapsulation layer, formed on the device wafer and covering the first chips, wherein the first encapsulation layer has a first opening exposing at least one first chip of the plurality of first chips and the chip back surface exposed by the first opening is connected to a loading signal;
- a metal layer structure, covering the at least one first chip exposed by the first opening, a bottom and sidewalls of the first opening and a top of the first encapsulation layer, wherein the metal layer structure includes a back metal layer alloyed with the chip back surface by an alloying treatment between the chip back surface and a portion of the metal layer structure on the chip back surface; and
- a second encapsulation layer, formed in the first opening, covering the back metal layer, and further covering the metal layer structure on the top of the first encapsulation layer.
2. The structure according to claim 1, wherein: the loading signal is one of a ground signal and a voltage signal.
3. The structure according to claim 1, wherein: the loading signal is a ground signal; and the second encapsulation layer contains a second opening therein to expose the back metal layer.

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4. The structure according to claim 1, wherein: the loading signal is a voltage signal; a plurality of second chips are formed in the device wafer and a second pad is formed on a surface of the second chip of the plurality of second chips facing the first chip; the first opening exposes the second pad; and the metal layer structure is also formed on a surface of the second pad.
5. The structure according to claim 1, wherein: the metal layer structure includes a bottom metal layer, a transition metal layer on the bottom metal layer and a top metal layer on the transition metal layer.
6. The structure according to claim 5, wherein: the bottom metal layer is made of a material including Ti, Cr, Al, V, or a combination thereof; the transition metal layer is made of a material including Ni; and the top metal layer is made of a material including Ag, Au, or a combination thereof.
7. The structure according to claim 5, wherein: a thickness of the bottom metal layer is of about 1000 Å to about 5000 Å; a thickness of the transition metal layer is of about 1000 Å to about 5000 Å; and a thickness of the top metal layer is of about 1000 Å to about 50000 Å.

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